H.M.S. 'AMAZON'

THE BIRTH OF A GENERATION

BY

LIEUTENANT-COMMANDER B. J. McD. GOWANS, C.ENG., M.I.MECH.E., F.I.MAR.E., A.M.B.I.M., R.N.

(*The first Marine Engineer Officer of the ship*)

Many teething troubles are inevitably associated with the introduction of a new machinery concept (COGOG) into the Fleet. This article recounts the problems that were experienced during the development of the engineered package. The solution of the various problems leading to the successful acceptance of H.M.S. *Amazon* shows that the design augurs well for the future of the Types 21, 42 and 22 Classes.

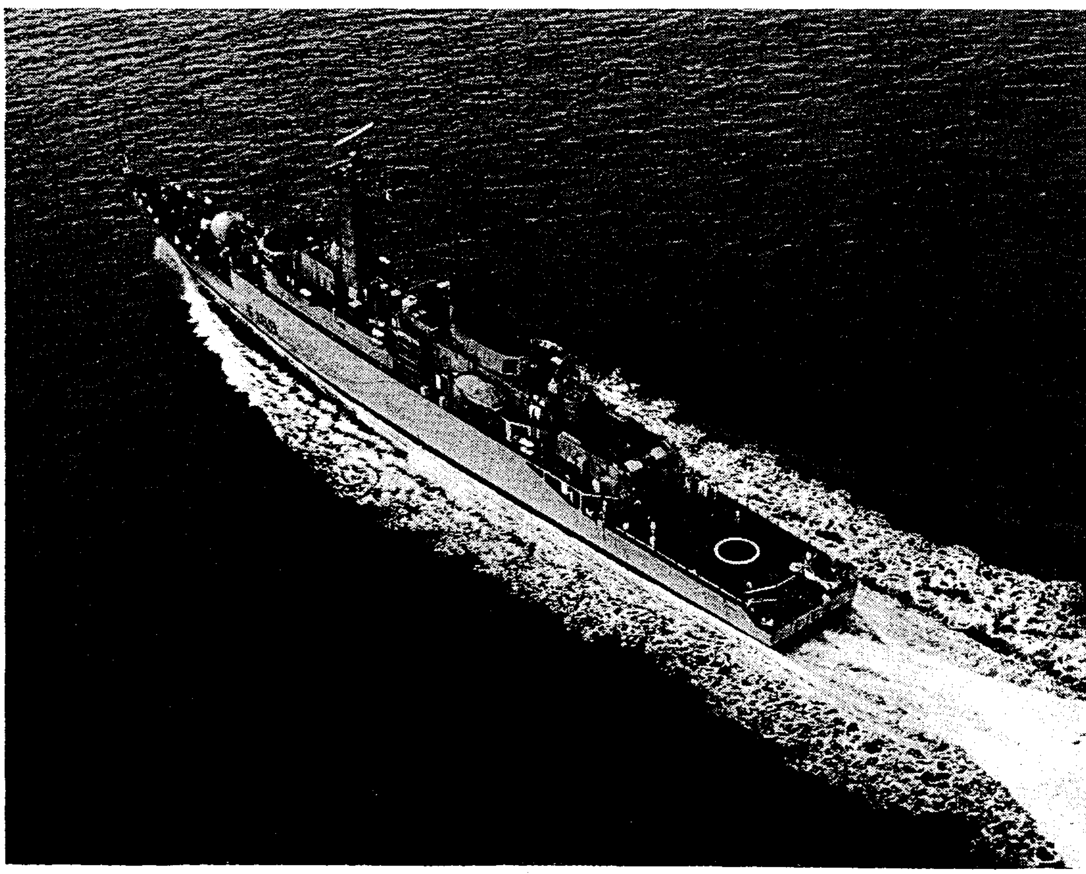

FIG. 1—H.M.S. 'AMAZON'

It is intended that this should be seen not as a chronicle of disasters but rather as how technical problems can be successfully overcome, given the will and the necessary ability.

Concept

The conceptual design was conducted by Vosper Thornycroft Ltd. and Yarrow Shipbuilders Ltd. After the contract for *Amazon* was placed, Vosper Thornycroft undertook the detailed design and the lead-yard services.

The ship's tonnage is in excess of 2800 but in size the ship is noticeably larger than a *Leander*. This is due to the use of a large amount of aluminium in the superstructure, internal bulkheads and decks. The weapons fitted include a 4·5-in. Mk 8 gun-mounting, Seacat and 20mm guns, and the ship will eventually carry a Lynx helicopter. The weapon fit of later ships will be gradually improved as equipment becomes available. The space for stores, accommodation, victualling arrangements, machinery, weapons and operations are each grouped separately. The accommodation for chief and petty officers is in three-berth cabins with separate recreational lounges. Junior ratings sleep in four-berth cubicles around recreational areas in three messdecks. There are separate dining halls for senior ratings and junior ratings adjacent to the galley. The ship is fully air conditioned and fitted out making the maximum use of modern materials in order to decrease the husbandry task.

Design

The machinery is in four main compartments. The twin-shafted plant giving a speed in excess of 32 knots is arranged as shown in FIG. 2. The following are outside the main machinery box:

York Shipley refrigeration machinery

Hall Thermotank direct-expansion air-conditioning plant (4 plants at 540 000 BTU/hr)

Avcat pump space (also contains upper-deck hydraulic machinery)

Steering gear compartment

The ship control centre (SCC), which also forms the damage control HQ 1, containing the Hawker Siddeley Dynamics machinery control console and the switchboard control console

An engineers' workshop, a shipwrights' workshop and a ventilation/filter-cleaning workshop.

There is a technical office for the MEO and the WEEO and their writer. The CMEA shares a maintenance planning office with other Departmental Chief Petty Officers. The ship is described in more detail in Ref. (1).

The propulsion machinery is all gas turbine in COGOG form and is generally similar to the Type 42 destroyers (*Sheffield* Class). The systems are mainly new in concept since they support a new form of propulsion plant. The equipments are selected by the ship designers except for certain items from the SYMES range. The design concept for the ship and major equipments has already been described in Refs. (1), (2), (3), and (4) but TABLE I below shows which of the systems or equipments are new.

A $\frac{1}{12}$-scale model which was used to position the machinery is now at H.M.S. *Sultan*. Small items of pipework were not modelled; deck plates, gauges, extended rod-gearing, etc. were positioned during the build and as-fitted drawings were produced. From isometric drawings, the pipework was made and then taken to the ship for hanging. This preciseness of design was in order to achieve a very high degree of similarity or identicality between all eight ships of the class, three of which (*Amazon, Antelope* and *Active*) are built by Vosper

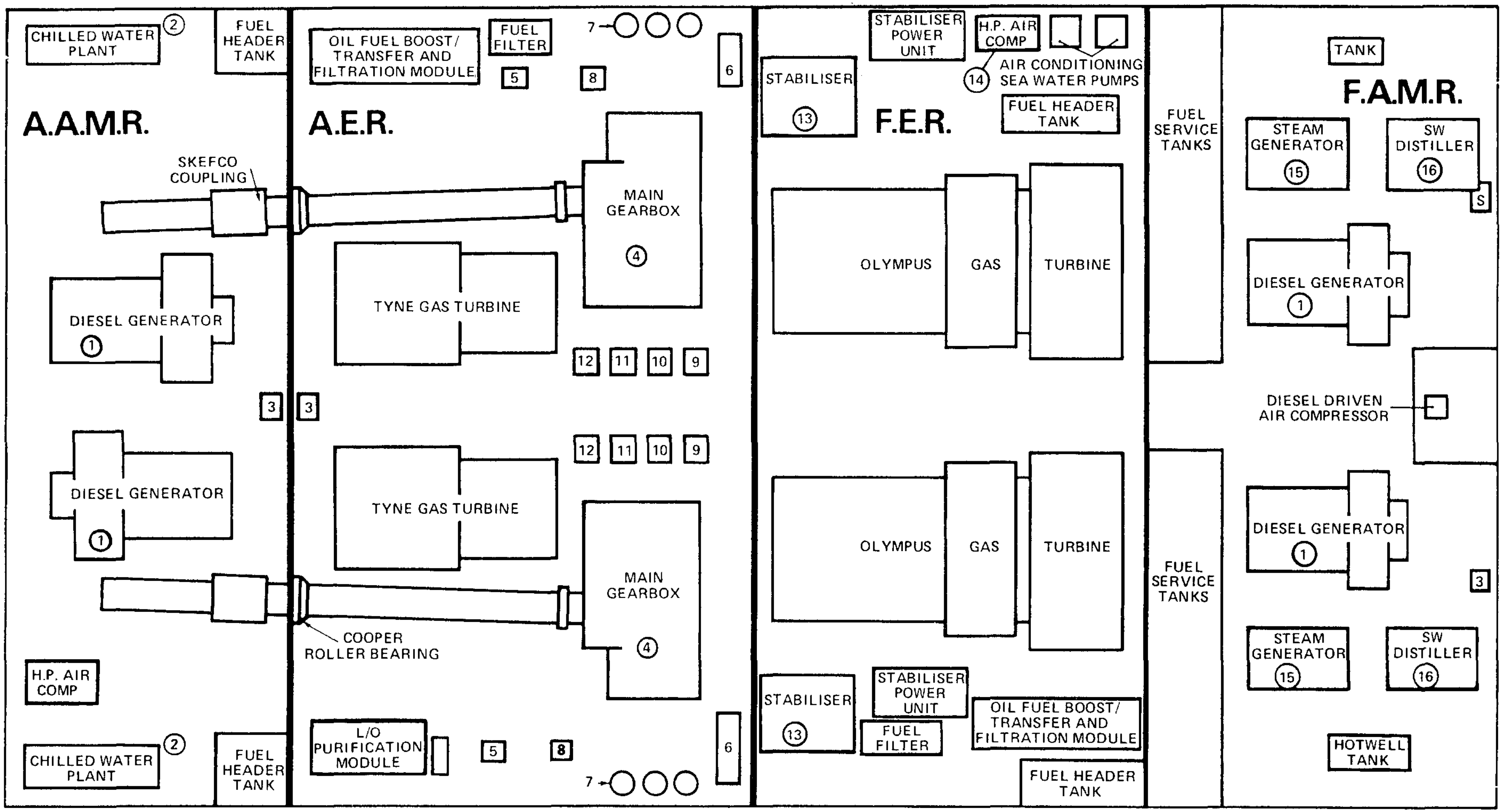

FIG. 2—TYPE 21 MACHINERY LAYOUT

(1) 750 kW diesel generator.
(2) 420 000 BTU/hr chilled-water plant.
(3) 150 tons/hr hull and fire pump.
(4) Main gearboxes.
(5) Motor-driven CPP pump.
(6) Main L.O. cooler.
(7) Main L.O. filters.
(8) Shaft-driven CPP pump.
(9) Shaft-driven L.O. pump.
(10) Hydraulic oil module.
(11) Motor-driven L.O. pump.
(12) Shaft-driven sea-water circ. pump.
(13) Fixed-fin stabilizer.
(14) H.P. air compressor.
(15) 4500 lb/hr steam generator.
(16) 300 gall/hr sea-water distiller.

TABLE I—*Comparison of systems and equipments*

System/Equipment	*Similar Equipment in service*	*Similar in Type 42 Class*	*SYMES Range*	*New Concept*
Olympus TM3B		X	X	
Tyne RM1A		X	X	
Gearbox		X	X	
CPP and system		X	X	
Control console		X	X	
Propulsion control		X	X	
Auxiliary control				X
Steering system				X
Generators	X		X	
Auxiliary boilers	X	X	X	
Steam system		X		
Evaporators				X
Air conditioning				X
Refrigeration	X	X	X	
Chilled water system				X
Stabilizers	X	X	X	
Fire pumps	X	X	X	
Salt water system				X
H.P. air system		X		
Fuel system				X
Avcat system	X			

Thornycroft Ltd. and the other five (*Ambuscade, Arrow, Alacrity, Ardent* and *Avenger*) by Yarrow Shipbuilders Ltd. From the basis of detailed drawings, the cataloguing of all components of the ship was possible on computer file. The ship was built under configuration management where the Master Datum Base for the class is clearly defined and documented and any changes during build of the class are strictly controlled. Some changes, however, were made so as to align the Type 21 frigates more closely to the Type 42 destroyers (e.g. main machinery control and controllable-pitch propeller system); others were necessary to achieve a compatible total system as the design of each of the components was completed. These are described later as they affect the build programme.

Build

The ship was laid down on 'A' Berth at Woolston on 16 November 1969. The major structure was completed and large auxiliaries (diesels, evaporators and boilers) were shipped before launch. The shaft lines were bored straight by line-of-sight through the A- and P-brackets, stern-tube water-lubricated bearings, mechanical seal and the one bulkhead roller-bearing. The shafts were

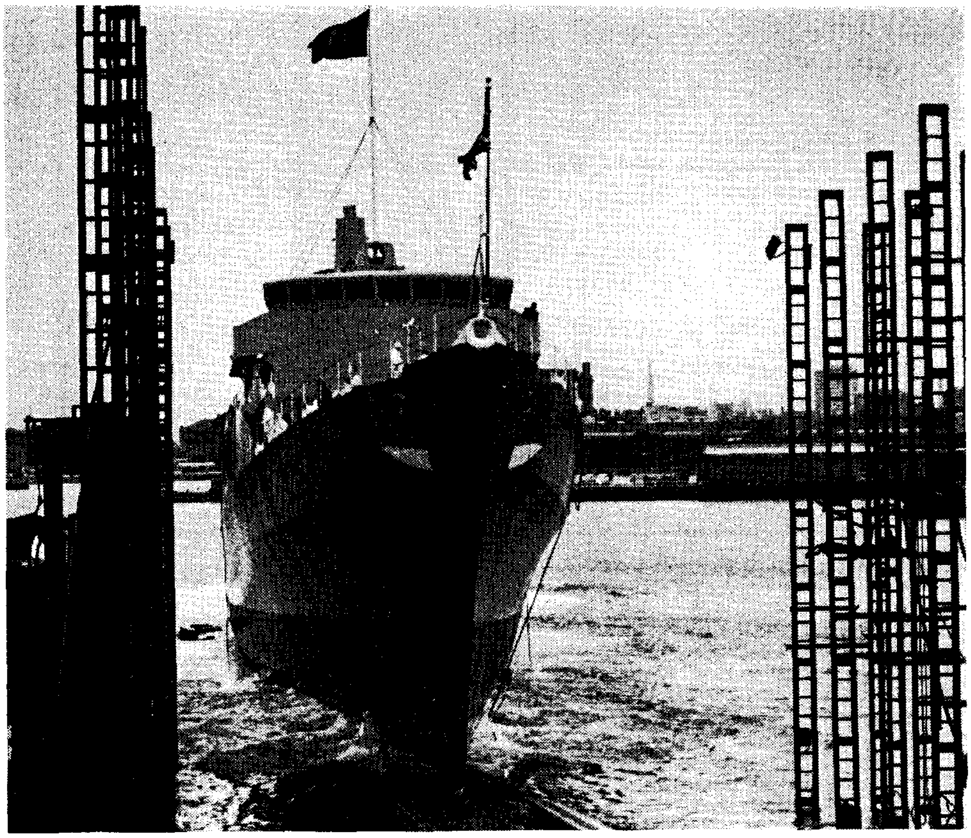

FIG. 3—'AMAZON' BEING LAUNCHED

fitted and the sections joined by Skefco hydraulic-shrink couplings. CPP oil-transfer tubes were not fitted at this time and weighted blanks were positioned in place of the propellers.

The ship was launched on 26 April 1971 by her royal sponsor, H.R.H. the Princess Anne.

After launch, the remainder of the large auxiliaries were installed and the gearboxes shipped. The main and cruise modules (power turbine (Olympus), bedplate and primary gearbox (Tyne), and acoustic enclosures) arrived and were shipped and the ship's structure was closed. Weight and space plastic simulators of the gas turbine change units were then shipped using the removal guide-rail arrangements. Cascade bends were then fitted, followed by the intake splitters and exhaust silencers.

In order to ensure the correct main-wheel bearing loadings, the shafts were allowed to droop forward from the bulkhead bearing and the gearbox was then aligned to achieve a calculated offset and gap between the gearbox flange and the main shaft flange. This was done in stable conditions of early morning to avoid the effect of sun and other ambients hogging the ship.

The gearbox was chocked and the truth of its datum planes was checked by an optical sweep using telescope and targets. The engines were then optically aligned to the gearbox with allowances for thermal growth and movement of the resilient mounts due to torque reaction. The acoustic enclosures and cascade bends were then aligned to the power turbines and from these the uptakes and downtakes, splitters and silencers were aligned. Further calculations showed that the initially calculated offset was incorrect and it was found necessary to raise the bulkhead roller bearings on an eccentric ring to correct this.

The various pipe systems were installed in the ship, having been flushed ashore and positioned in the ship under the inspection of quality control and

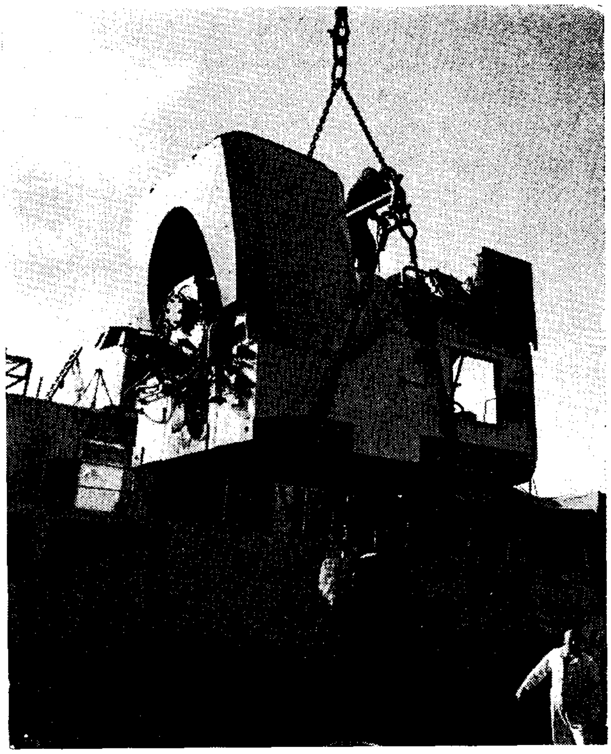

FIG. 4—SHIPPING OF OLYMPUS POWER TURBINE

naval overseers. The hydraulic system for the CP propeller was installed in sections, each flushed to ASTM 4 cleanliness standard using a hydraulic rig. Outside-machinery systems were installed; these included the automatic water-spray system throughout the aluminium superstructure, the upper-deck hydraulic system and the ventilation trunks from the direct-expansion air-conditioning plants. Detailed inspections of these were carried out by the Dockside Test Organization, on which the ship's staff were represented.

The ship docked at Southampton on 5 November 1972 to fit the propellers and stabilizers and to modify certain sea-tubes. A large plastic tent was built under the stern of the ship to act as a clean area for fitting the CPP outer and inner oil-transfer tubes which pass the propeller actuating oil. These tubes, which come in 16-ft. lengths, are mechanically jointed. The task in dock was therefore:

(*a*) Install outer oil-transfer tubes.
(*b*) Install inner oil-transfer tubes.
(*c*) Flush and pressure test.
(*d*) Fit propeller hubs.
(*e*) Fit oil-transfer boxes.

Special equipment is required and the task was done on one shaft at a time. The task is complicated by having to thread the hub and oil transfer box over the tubes.

Although the ship undocked on programme, there were major problems, namely:

(*a*) There were 9 mm of lost motion somewhere in the oil-transfer tubes. To obtain the required accuracy of pitch, this was unacceptable. At a later docking, it was found that one of the inner-tube couplings was not tight allowing axial movement.

(*b*) The butterfly valves used in the salt-water system were corroding at the pins which hold the valve to the spindle, and the spindle was prone to shear. As there was a large number of valves involved, the modification of spindles and pins became a major task.

(*c*) The gearboxes were to be opened to carry out a modification to the SSS clutch pawl and pawl rings; this had been found necessary as a result of shore trials. The cramped conditions in the after engine room (due to the protective arrangements built over the gearboxes) had some delaying effect on the machinery programme.

(*d*) The Keelaring couplings used in the H.P. air and hydraulic systems were found to need more accurate installation than had been realized. All the couplings (about 2000) had to be remade and torqued. As the systems were in use, the pressure was dropped for safety and the task done at night. Later the H.P. air line was contaminated by salt water and this started corrosion on the bodies of the mild steel couplings. This corrosion has remained active due to the dampness of the H.P. air.

Despite these problems, there was considerable pressure to hold the programme date for contractor's sea trials. Inspection and testing began in earnest. The test forms had been written during the previous two years with the best technical knowledge available; what they lacked, however, was the flexibility to enable them to be used on a part of a system as it became available. There was also at this time a number of production problems:

(*a*) The main fuel system consisting of a transfer and boost system with associated tanks (which are not coated) took sixteen weeks to flush clean.

(*b*) The Olympus power turbines took five weeks to flush clean because of contamination including flakes of internal paint.

(*c*) Due to the failure of the Olympus engine rubber mounts, solid mounts were fitted to enable the trials programme to be carried out; this necessitated a second alignment.

(*d*) Due to inadequate bonding to the metal backing-plates, the Tyne rubber mounts split. They took some time to settle and it became necessary to re-chock the engine.

(*e*) The factory production test of the electronic control system was done in the ship, and it was then connected to the ship's system and equipments. This showed up many problems typical of a first-of-class. There were many cases where the interface between the ship and the control system was not compatible—voltages were wrong, transducers were not fitted or wiring was not available.

Each problem as it arose had to be resolved between a number of parties. Gradually, however, each problem was overcome, each system tested, and each equipment set to work. The shipbuilder worked a seven-day 80-hour week with *Amazon* the major user of labour in the yard. Both ship's staff and PNO's staff were present throughout and it became very much a corporate effort.

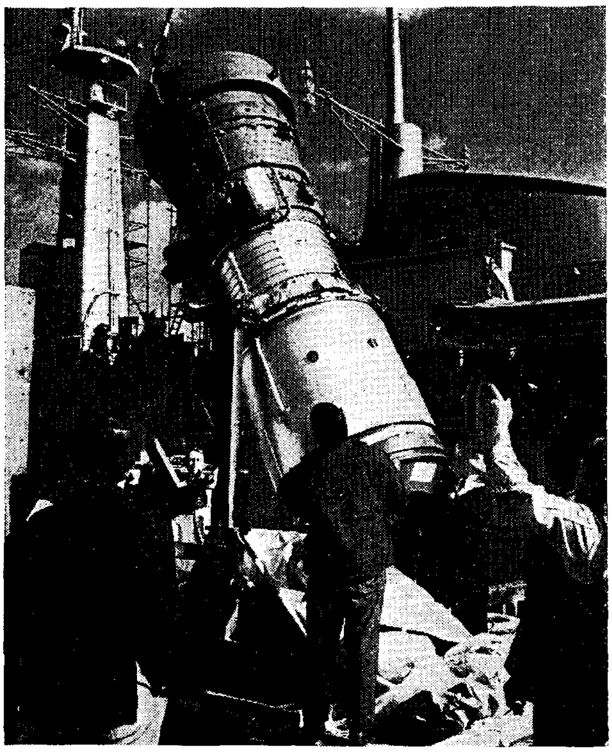

FIG. 5—SHIPPING OF OLYMPUS GTCU

The plastic simulators were removed and the main and cruise gas turbine change units were installed in March 1973 using the shipping arrangements intended for normal GTCU changes. The engine supplies were connected and the gas turbines were made ready in six weks. The engines started first time and they remained reliable thereafter.

The controllable-pitch propellers were set to work after docking to cure the lost motion in the port hydraulic tubes. The initial setting-to-work showed the need for some minor system modifications and also presented the first of a number of failures of the

CPP hydraulic pumps. In a short period, two pumps were changed because of inaccurate servo controls and one because the port plate had lifted causing loss of boost pressure.

The final part of the propulsion system to be set to work was the controls. The system is electronic and contains a number of sub-systems, such as:

(*a*) Start and stop logic system and surveillance for each engine.

(*b*) Power/pitch control system from a single lever for each shaft.

(*c*) Surveillance of transmission system.

(*d*) Control and surveillance of auxiliaries.

(*e*) Control of fuel.

The system was set to work in three phases with test group documentation drawn up in consultation with HSDE Ltd. and the machinery control trials team (MCTT). The setting-to-work was often hampered by defects in or non-availability of the system to be controlled. There was a number of changes found to be necessary, in particular to the actuators which move the swash controls of the pitch-control hydraulic pumps.

Just before basin trials, however, the Ministry of Defence decided that the control system was unsafe and it was switched off for modification. The problem arose through the earthing arrangements: the control system was designed for the zero-volt line to be floated independently of the ship's earth potential and with an earth detector fitted to positive and negative lines. However, because the ship's wiring distant from the panel and the components at the other end (on engines, etc.) were not isolated from earth, earth potential was put on the console through these parts. Eventually, all these wires were isolated from earth and reconnected. The zero-volt line in the console then took up a potential of 1·5 volts due to leakages, a condition worse than the original. The zero-volt line was then connected to ship's earth through the shunt of an ammeter. Although leakages have shown since then, they do not seem to have had any effect. Major modifications will be undertaken to clear this matter in the long term.

A dynamic data retrieval (DDR) system was fitted: this allows recording of variations of some thirty selectable outputs of the main propulsion system on ultra-violet recorder paper. For sea trials, this was augmented by instrumentation provided by the Admiralty Engineering Laboratory and the Yarrow Admiralty Research Department and by a continuous reading tape recorder.

Basin Trials

Recognizing the participation of the ship's staff during setting-to-work and the amount of training they had undergone on the simulator at H.M.S. *Sultan*, the shipbuilder requested the services of watchkeepers on the control console. From then on, whenever the shafts were turning, watches of two chief petty officers, a petty officer and a LMEM under one of Vosper Thornycroft's engineering managers (who had also undergone a course of training at *Sultan*) were closed up. This was exceedingly good experience for the ship's staff who, therefore, remained totally involved with the progress of the trials.

The setting-up of the shaft-driven CPP pump presented a problem since it had to be set up to the zero-pumping position with shafts rotating. It was considered that there was a danger to *Antelope* and *Active* astern and to the Woolston chain ferry ahead if this was done alongside and so the ship was taken into the river. In fact, the setting-up was achieved without violent movements. The zero-thrust position of the propeller blades was also set up so that alongside runs could be safely done thereafter. The test group completed its final propulsion test activity which included running one engine at a time on each shaft and changing over. Pitch was limited to 3° ahead and astern on opposite shafts. Before undergoing the official basin trial under the machinery trials unit (MTU), the machinery was tried by the staff of the Principal Naval Overseer under the Naval Engineer Overseer.

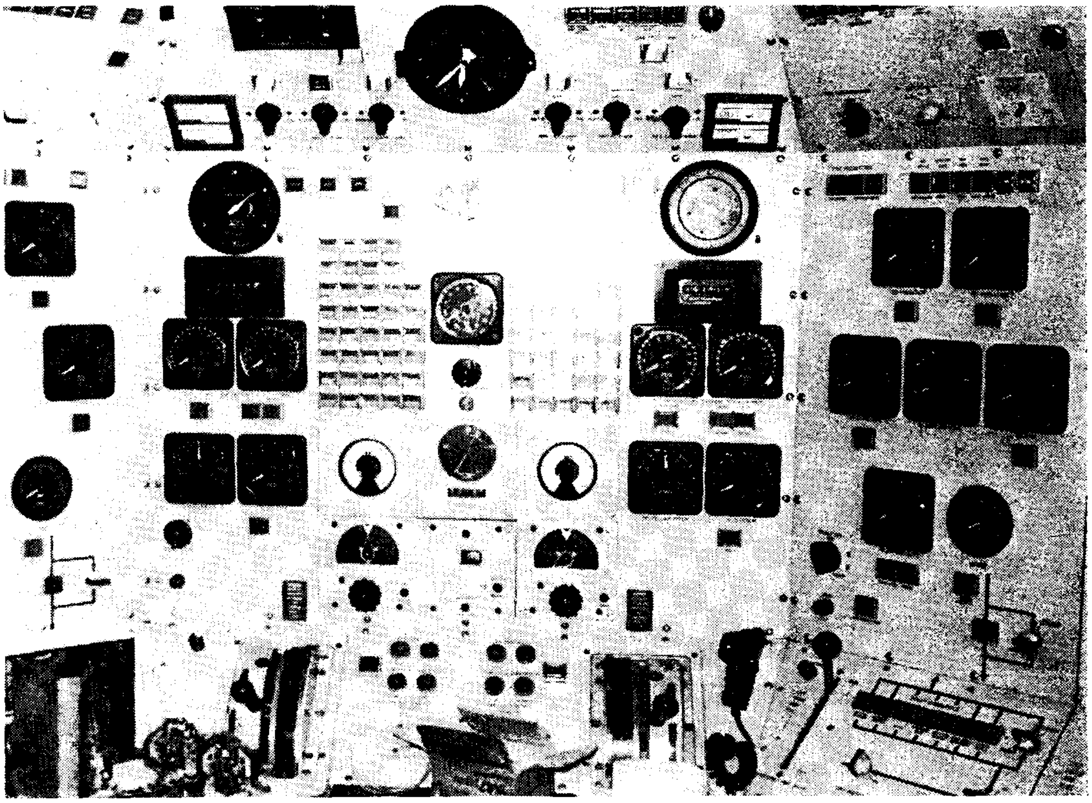

FIG. 6—TRANSMISSION PANEL WITH TYNE ENGINE CONTROL PANEL ON RIGHT

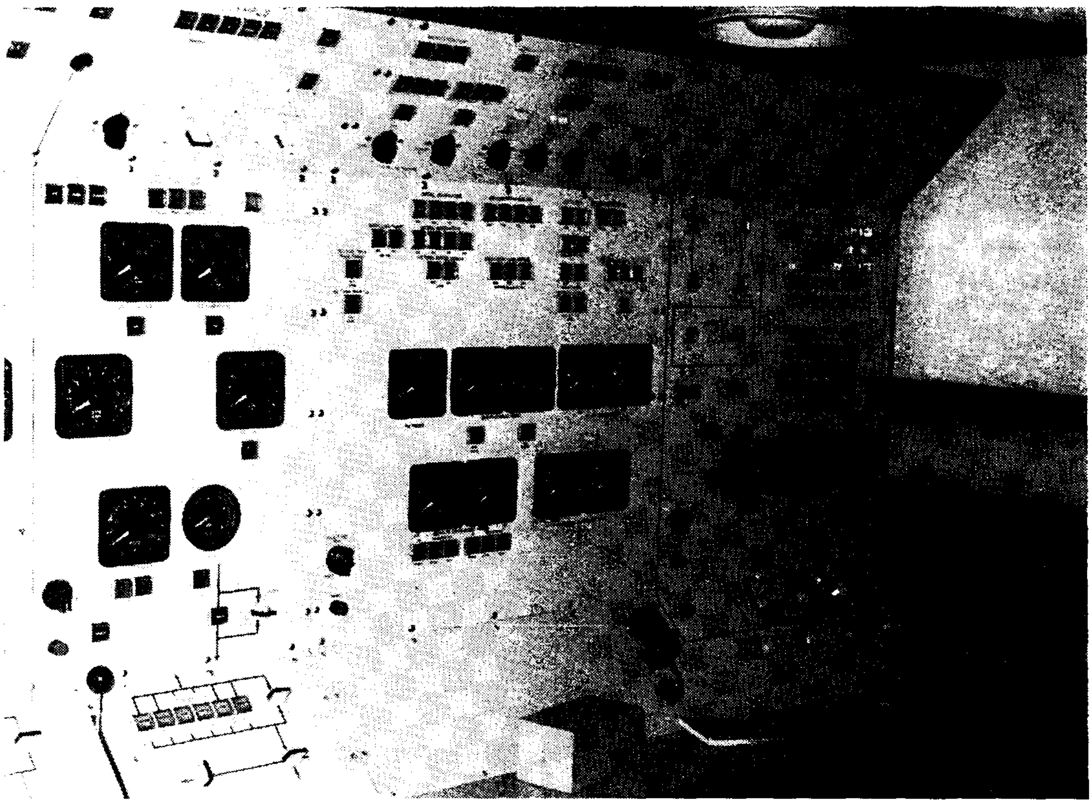

FIG. 7—AUXILIARY PANEL CENTRE, STARBOARD OLYMPUS ON LEFT, FUEL CONTROL PANEL ON RIGHT

This rapid preparation for sea trials put a large strain on the men and machinery. Although there was a considerable amount of work uncompleted, the machinery was considered reliable enough and the ship safe enough for contractor's sea trials which began on 20 July. Only eighteen days had been lost on the date set over six months before, despite a considerable number of setbacks.

Contractor's Sea Trials

Contractor's sea trials were conducted in three parts separated by periods for defect rectification and design investigation. These follow in sequence:

Period 1 (4 days)

Amazon sailed on Tyne engines from Southampton at 0803 on 20 July 1973. The ship performed properly from the first movement and during this period reached close to full power on Tyne and on Olympus engines. Problems did occur but it is significant that they were repeatable, not random. These problems included:

(*a*) Main gearbox high-speed bearing temperatures exceeded limits at higher powers.
(*b*) The port plates in the gear-driven CPP pumps lifted resulting in loss of boost pressure.
(*c*) The air non-return valves in the propeller blades leaked allowing water up the shaft.
(*d*) Considerable loss of oil resulted from the gearcase becoming pressurized because the torque tube acted as an air pump.
(*e*) The seals of the oil-transfer box failed.
(*f*) There was excessive pitch wander.
(*g*) The shaft brakes rubbed on their discs which became red hot. Despite a number of modifications, the brakes were unable to accommodate the axial movement of the disc associated with ahead and astern transients.
(*h*) The shear pins (fitted to prevent overloading of the pump gearing) on the drives of all pumps driven from the gearbox failed regularly. Investigations indicated that this was partially caused by the control system that makes the pumps run up quickly and partially due to inadequate pin size. In the case of the CPP pumps and the salt-water pumps, this was overcome by increasing the shearing cross-section and changing the material. In the case of the hydrostatic drive to the lubricating oil pump, these modifications did not resolve the problem and it was subsequently discovered that misalignment of the pump and also pressure surges in the system contributed to the failure.

The initial trials period was considered satisfactory, At this time, the ship was docked at Portsmouth for underwater work associated with the weapons, and the opportunity was taken to investigate and rectify these problems.

During the period in dock and afterwards at Southampton, the defects were rectified where possible and much of the outstanding work (such as rod-gearing) was now done. These included:

(*a*) Fitting vibration transducers on the bearing caps of the gearing high-speed line.
(*b*) Fitting bearings with annular grooves having a greater oil throughput to overcome the overheating problem.
(*c*) Modifying the CPP pumps to prevent collapse of boost pressure due to lifting of the port plates.

(*d*) Modifying the breathing arrangements of the gearbox to prevent air being drawn in through the torque tube.

It is believed that many were surprised at the size of the ship, having expected one of Vosper's smaller frigates. One sailor was heard to remark that he didn't know what it was, but it couldn't be one of ours! The Admiralty Master took the ship into 'B' Lock under her own power without tugs—an indication of the feeling of reliability already prevalent.

Period 2 (4 days + 1 day)

The ship carried out test group check and basin trials before resuming CSTs on 24 September. During this period, more of the MTU's preliminary trials were attempted, and these showed up some new problem areas:

(*a*) The accelerometers fitted to the bearing caps on the port gearbox gave readings considerably in excess of the MOD acceptable value at full power (this was despite the fact that a 50-penny piece sat happily on its edge). Readings of 0·53 in./s were measured on the port box at once-per-revolution of the high speed line; the figure for the starboard gearbox was 0·23 in./s which is marginally below the MOD short-duration limit. The vibration exhibited a step increase at irregular intervals due to the non-linearity of the system stiffness. It apppeared that the high-speed line of Olympus power turbine, torque tube, and SSS clutch was sensitive to concentricity, balance and alignment.

(*b*) The Olympus engines failed to accelerate following a 'crash' manoeuvre from a high power ahead to astern when the gas generator speed is reduced to idling, and they tripped out on high turbine-entry temperature.

(*c*) A total electrical failure occurred due to a fault in the circuits of the automatic watchkeepers on the diesel alternators. This showed up a number of difficulties with emergency lighting and communications. It also served as a reminder that much of the machinery local and remote indication is lost and that the system does not 'fail set'. The output from the CPP hydraulic pump is controlled by the error between desired and actual pitch. The swash-plate control is, in fact, hunting very slightly positive and negative within the deadband of the system. At the instant of total electrical failure, one gear-driven pump had its swash marginally ahead and the other astern. As the shafts continued to rotate with the engines running on fuel header-tank supply, one pump moved its propeller onto the ahead mechanical stops in the hub. The other propeller was gradually pumped towards full-astern pitch. Luckily, control was restored quickly since the engine had fuel set for about 18,000 s.h.p., much greater than the astern power limit. Without a servo manual system, the only alternative would be to trip the engine mechanically.

The CST programme was postponed while a number of investigations were carried out on Olympus stall and high-speed line vibration problems. These included the use of the Olympus and CAH test rigs at Rolls-Royce, Ansty, and trials alongside and at sea in *Amazon*. The results of these investigations were:

(*a*) that a new design of stiffer torque tube was required in order to push up the critical speed. Until this was available, *Amazon* would have the engine aligned to the gearbox within very tight limits and the torque tubes placed in position of accurate concentricity and in-place balance.

(*b*) that the acceleration control of the Olympus engines needed to be modified to overcome the stall problem. This was done in such a way that it did not affect the very high speed of response of the ship as a whole.

Period 3 (8 days)

Amazon finally restarted CSTs on 11 December 1973. After various preliminary trials of systems and domestic equipment had been undertaken to the satisfaction of the MTU, the main engine trials were resumed, gradually culminating in a six-hour full-power trial on Tyne and on Olympus engines.

The full-power trials were conducted in fairly rough weather which the ship took well despite being in the light condition. The sea was choppy with a force 10 wind blowing up considerable spray and for this reason the full-power trial was carried out in the shelter of the French coast. An intake filtration system involving 'hook-type' Peerless spray eliminators followed by monel knit mesh is fitted in *Amazon*. Some break-through was seen, although this was partly due to inadequate drainage of collected water from the air flow. Because of the limited time remaining available before Christmas, the final astern manoeuvring trial was conducted in the dark in Southampton Water!

The ship berthed on 20 December and the results were then assessed.

Period Post CST to Ship Acceptance

The assessment early in January 1974 was that the performance of the ship and all her machinery compared very favourably with the predicted performance and with previous first-of-class ships; there were, however, certain problems still to be solved and modifications to be incorporated.

(*a*) As already mentioned, the need to fit stiffer torque tubes to cure the vibration in the gearing high-speed line, the increased stiffness being achieved by a larger diameter and repositioned flanges. The lead time for these was some six months.

(*b*) Although the control system had functioned well with few faults, the trials had shown that fuel schedules still needed to be optimized. Some minor modifications also still needed to be incorporated.

(*c*) During trials, the Tyne clutches showed a disinclination to disengage, and the logic of the engine change-over controls therefore needed to be altered to prevent two clutches being locked in together on the same shaft. Although the response time for the change-over phase was increased, this is still acceptable.

(*d*) Minor redesign work was required to the AVR and automatic watchkeepers on the diesel alternators to prevent the controls unlatching and hence causing a cascade failure of the power source.

(*e*) Certain system modifications were shown to be necessary. In particular, unitization of the suctions both of the fuel purifiers and the lubricating oil purifiers. Also, although the H.P. air system was now airtight, the corrosion of the Keelaring couplings was widespread—reducing stations were beginning to show the effects of corrosion products. The performance of the upper-deck hydraulic system was found to be below test specification.

(*f*) The air non-return valves in the propeller hubs were still leaking and L.P. air pressure was necessary to prevent sea-water leaking into the gearbox through the oil-transfer box.

It was decided that the work involved together with the demonstration of engine changes could be completed in time for the planned commissioning date of 11 May 1974.

Additional work, however, became necessary as a result of further opening up and examination of machinery. On inspecting the port gearbox, white metal was seen in the area of the thrust bearing locating the primary wheel and it was found that the forward thrust ring had failed. The starboard gearbox was inspected and it too showed a failure, this time on the after face. Although it was difficult to produce a mode of failure that satisfied both these, the consensus of opinion was that, in a CPP-propelled ship, the speed/torque relationship may be sufficiently different from a conventional system and that the fine tooth quill-shaft coupling can lock solid instead of sliding. Larger load-carrying capacity of the thrust bearings was required and so pivoting-pad thrust bearings needed to be substituted.

Together with industrial problems and the three-day week, this finally broke the programme since there was a long lead time for the bearings and it was decided that the first set should go to H.M.S. *Sheffield* so that she could safely start her CSTs. Furthermore, having two gearboxes open and tented completely prevented other work in that engine room.

As it was still in the interest of the shipbuilder and of the MOD to make the planned acceptance date, it was decided that there should be a partial acceptance of the ship, deferring the completion work in the after engine room, the sea trials and the engine change demonstrations. This was achieved and the ship was accepted on 4 May 1974. The acceptance form, D448, was of considerable length, reflecting the speed of completion and the amount of deferred work.

H.R.H., the Princess Anne, attended the commissioning ceremony at Southampton on 11 May 1974 and, together with the ship's company and their guests, enjoyed a memorable day. The ship was adopted by the City of Southampton. She had been finished to the highest standard, and all associated were rightfully proud of her.

Down below, however, the work was progressing. The starboard Olympus GTCU was removed and replaced as a demonstration; this showed that the task could be done in less than the 48 working hours programmed, even on this first occasion. Although the crane driver was from Southampton Docks and used to 'full up, full down' operation, he nevertheless had little trouble lifting out his most expensive load ever.

Michell-type thrust bearings were fitted in the gearboxes and the machinery was made ready for a shake down passage under the White Ensign to Portsmouth and to dock for changing the propeller blade non-return valves. *Amazon* sailed from Southampton on 29 May as programmed. The ship's company had a feeling of some satisfaction at being alone without shipbuilders, contractors and overseers for the first time—and at the same time had a feeling of some trepidation.

The ship docked on No. 12 Dock at Portsmouth on 31 May. Due to a breakdown of communication with the dockyard, it had neither been realized that the ship's company would be living on board nor that the overside services of these ships was different from, say, a Leander. Although the first few days in dock were difficult domestically, the work went very well. Each propeller blade was removed and the non-return valves changed—a very efficient first-time effort.

The underwater condition was generally good although there was a large number of small barnacle-like shells around the stern. These had grown on the shaft in way of the water-lubricated shaft bearings and, on first turn of the shafts, became grinders rapidly causing bearing wear-down. This was monitored weekly thereafter and appeared to be stabilizing.

In the after engine room, the new torque tubes were fitted, both gearboxes were opened for fitting the new thrust bearings and the starboard Tyne GTCU was removed for demonstration. In order to check the effectiveness of the new torque tubes, a number of accelerometers and transducers were fitted to measure the accelerations and displacements of the vibrations in the high-speed shaft line. The vibration trials carried out alongside showed that the new configuration had reduced the amplitude of the vibrations by an order.

During the three weeks at Portsmouth, the engines, the gearboxes, the propellers and the controls had been taken apart and reassembled—the resilience of the machinery and of the men never failed to impress.

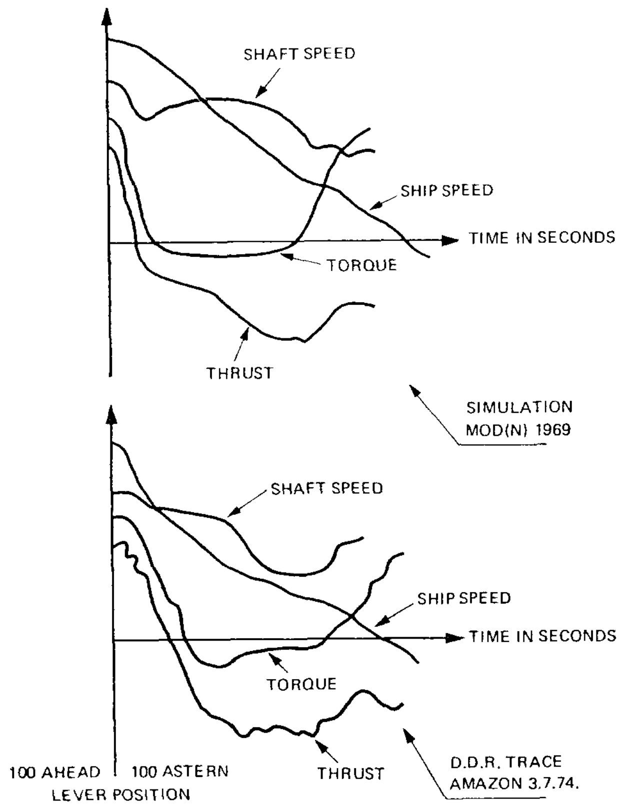

FIG. 8—COMPARISON OF MANOEUVRING TRACES

After a successful official basin trial, the ship sailed for sea trials on 24 June. The first two days at sea showed that the vibration in the high-speed line had been satisfactorily cured, and that the ship was now capable of full speed and full power and was ready for contractor's sea trials. The MCTT first checked the response of the control system including matching the engine fuel schedule to the requirements. This was not simple since the facility for screwdriver-type adjustment was not available (although this modification was incorporated later). The process was somewhat tedious as, after each adjustment, the trial had to be repeated; this, nevertheless, paid dividends as the parameters were set for the whole Class and very precise and repeatable control was achieved thereafter. It is interesting to compare the original computer manoeuvring simulations undertaken in 1969 with the actual traces taken from the DDR unit five years later. FIG. 8 shows the extremely good correlation.

After some weapon trials, the ship sailed on 29 June for the measured mile at Arran for first-of-class speed and turning trials, final machinery trials and intake trials. The intake trials, conducted by the Naval Wing of the National Gas Turbine Establishment, showed up certain inadequacies in the drainage arrangements allowing re-entrainment of removed water. Action was put in hand to incorporate interim modifications after some salt had been found in the low pressure stages of the Olympus engines.

The speed and manoeuvring trials, turning trials and stabilizer trials were tedious and physically wearing for all on board: for some five days and nights, the ship, in a light condition, rolled and weaved, stopped and started almost incessantly. As an indication of this, the rudders were put full over 76 times at high speed and 54 orders of full ahead or astern (100 per cent. lever position) were given. To be ready for trials each day, the ship's company worked at night when anchored.

The thrashing being given to the machinery began to show up weak spots. Keelaring couplings on the steering-gear hydraulics blew out; it appeared that the couplings were metric and the pipework imperial and this may have been contributory. The stabilizers became uncontrollable due to air being sucked into the hydraulic circuit through spring-loaded air purge valves; these were eventually changed for solid plugs. The stabilizer controls had to be modified to set the correct natural frequency of roll of the ship. Surprisingly, there appeared to be no problem with the fuel system even though such ship

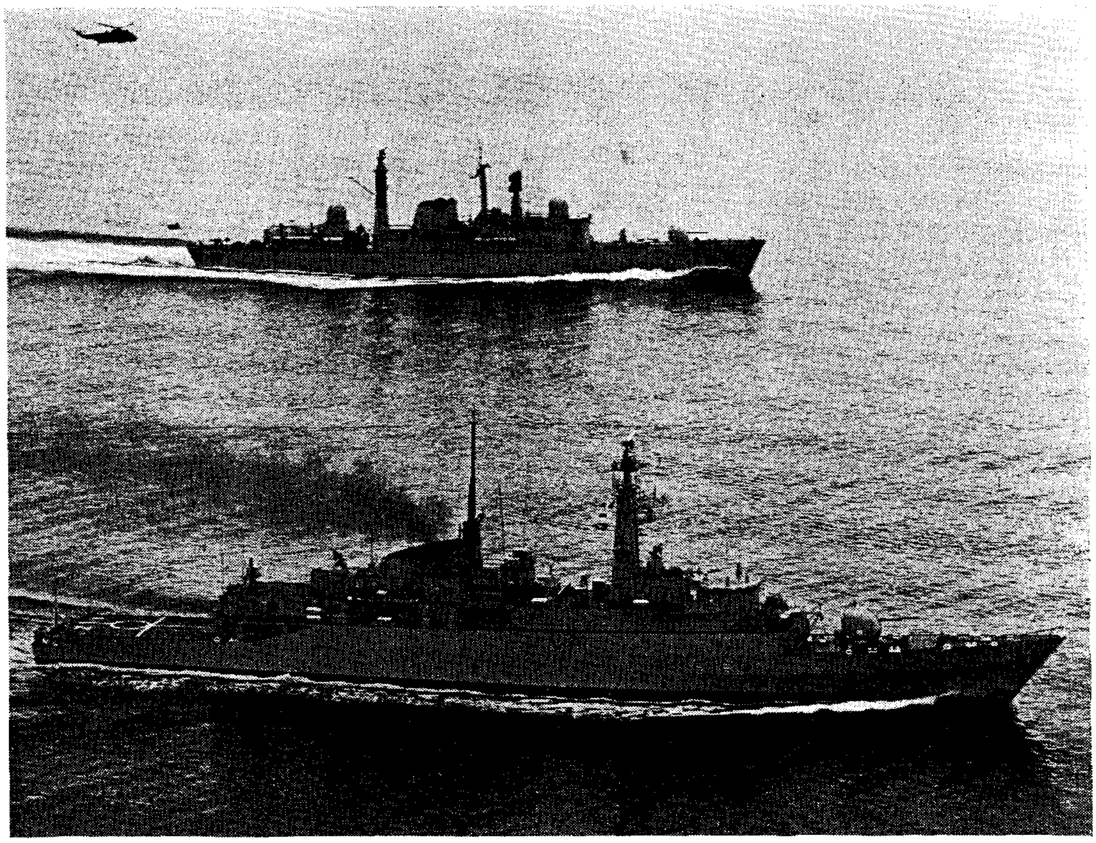

FIG. 9—H.M.S. 'SHEFFIELD' AND H.M.S. 'AMAZON' TOGETHER

movements must have stirred up the contents of the uncoated tanks. The filtration appeared to cope adequately; quantitative results were not, however, available. Fuel sampling points have subsequently been fitted.

The domestic boilers and diesel generators were a continuous sore providing the largest work load. When the evaporators are stopped the boilers have a light duty and at night only supply a calorifier. This caused excessive short cycling and eventual malfunctioning of the controls. The diesels were also suffering from underloading; the ship's load, which may be as low as 500kVA, is carried by two 750 kW diesel generators, giving an average of about one third load factor. There was some oil-throw from the crankshaft labyrinth seals which was diagnosed as being caused by back-pressure due to the arrangement of the crankcase breathers. The speeder, AVR and watchkeeper controls were all unreliable.

The lack of maintenance information exacerbated the problems. Although, by previous standards, there is improvement in the supply of BRs and PILs, the situation still leaves much to be desired. This problem was alleviated to some extent by the supply of some books in draft form, but still much time was expended searching for information or attempting to identify spares (some of which were incorrect). This situation, though not unexpected in a first of class, did increase the amount of overwork on board.

Further irritation was caused by a gradual deterioration of ventilation and air conditioning. The ventilation system went out of tune as some of the flaps in the trunkings came off their spindles. The air conditioning had not been set up because it was decided that this could not be done until tropical trials. The air supply to the messdecks and cabins gradually reduced towards an unacceptable level for living and sleeping.

When the servo control of a CPP pump became insensitive, the ship went to Faslane for 18 hours to change it, the work being carried out by ship's staff with assistance for slinging from the FMG. This break allowed the ship's company some rest and recuperation (and a good run ashore) after the arduous trials period. Another two pumps failed in the next few weeks and the ship's staff became proficient at these changes with FMG assistance; the efficacy of the upkeep by exchange was also proved.

A further break occurred when *Amazon* met up with *Sheffield* who had just started her CSTs. The photographic serial of the two new gas-turbine ships at high speed was gratifyıng since it was felt that many of *Amazon*'s troubles had contributed to *Sheffield*'s success.

The ship sailed south for Portland with final firings on the way. A Tyne on-engine fuel pump that failed on passage was changed and set up by ship's staff.

It is no exaggeration to say that the ship arrived for a FOST shakedown week physically exhausted and mechanically deteriorated. FOST's staff had a significant effect since they quickly assessed the situation and defined the problem areas. Their assistance started the upswing in the morale and effectiveness of the ship's company and alerted the Fleet staff to the overall situation. Although the shipbuilder was soon involved in the correction of the faults in the air-conditioning system, this was still not complete six weeks later. Updated BRs and PILs quickly became available.

During this period, the starting and idling of the Olympus engines became unreliable. The engine would start and idle with a low L.P. compressor r.p.m. so that the control system did not latch. The turbine entry temperature (TET) would then start to climb, although the r.p.m. of the spools did not rise. Eventually the TET trip would operate. The ship diagnosed sticking distributors and changed three. Rolls-Royce found no fault on testing the returned components. Finally, the problem was cleared by changing the burners. The reason for burner detrioration was to be investigated but may have been due to low power running. It also became apparent that the cleaning and inhibiting with WD 40 was attracting dirt onto the compressor blades and this may have been contributory.

The ship returned to Portsmouth for two weeks maintenance and leave. The shipbuilder had to complete all outstanding work before the final reading of the D448. The main gearboxes were opened to inspect the new thrust bearings, one Tyne GTCU was exchanged with a new unit modified to give a longer overhaul life, and modifications were carried out on the control system, boilers and diesels. This was another busy period. Just before sailing, another CPP pump failed and had to be changed.

Amazon sailed for more weapon trials on 27 July. The exchanged Tyne engine was set to work and tuned to the fuel schedule with comparative ease. Although another CPP pump failed, the redundancy in the system enabled the ship to continue her trials programme without limitations. This failure confirmed the need to modify the CPP system similar to that in *Sheffield*. The modification was to increase the servo pressure by the application of increased boost pressure. This was done by Portland FMG before the second week of shakedown.

The second shakedown week was spent at sea during which period a number of serials including towing, fuelling, replenishment and a high-speed run past H.M. Yacht *Britannia* were carried out. During this high-speed run, a fire alarm alerted and caused the port Olympus to be tripped. The alarm was caused by heat conduction from the engine to a sensor. The engine was back on line so quickly that any change in ship speed was unlikely to have been noticeable.

Much of the week was spent validating the machinery breakdown drills for FOST to approve; most of them were used during the damage control exercises

TABLE II—*Problem areas*

Main engines Olympus	Installation chocking and alignment Re-acceleration stall Distributor/Burner idling problems
Cruise engines Tyne	Installation chocking problems Short life combustion cans and fuel pumps
GT intakes	Water break-through
Main gearbox	Journal and thrust bearings SSS clutch pawls High-speed line vibration Gearcase pressurization Brake location Turning-gear strength and interlock
Propulsion Controls	Installation compatability Earth isolation Clutch logic Indication failures Alterations to settings
CPP system	Installation cleanliness Pump port plates lifting Pitch wander Sticking servo system Oversized system pressure Oil transfer box seal leakage Dirt, ex pump failures, flushing
Shafting	Installation shaft alignment Installation lost motion Seized pitch locking gear A-bracket wear down
Propeller	Leaking non-return valves
Generators	Low load running Unreliable controls Crankshaft labyrinth leakage
Boilers	Unreliability from light load
Steering gear	Low control output torque Hydraulic failures
Stabilizers	Hydraulic leakage Incorrect natural frequency
Air conditioning	Failed flap mechanism Air-conditioning controls not set up
HP air system	Rusted couplings Inadequate output
Salt-water system	Failure of butterfly valves
Upper-deck hydraulics	Below rated output, overheating
Auxiliary drives	Setting up Shear pin failures

at the end of the week. During the final exercise, another CPP pump failed. The ship sailed for Portsmouth to give leave and to prepare for deployment to the West Indies for hot-weather trials. During this two weeks, the other Tyne GTCU was exchanged by Portsmouth FMG. As there was evidence that products of the previous break-up of the CPP pump were now in the system and causing failure, a significant part of the system was stripped and flushed.

During the final maximum-speed run back to Portland, a time record may incidentally have been set up.

The achievements in H.M.S. *Amazon* are summarized in TABLE II. That all these first-of-class problems were overcome must reflect great credit on those who participated from the Ministry of Defence, the shipbuilder, the subcontractors, the MTU, the MCTT and the ship's company, and it must put the Royal Navy and its suppliers in a strong position on the world markets.

To the present Marine Engineer Officer falls the lot of settling the machinery down and evaluating it and also evolving the correct operation of the Department. The ship had a difficult political birth and a baptism of hard grind and suffered many disappointments due to delays but, because of the success, it has all been worthwhile. The indications are that these will be fine ships once inevitable teething troubles have been sorted out.

H.M.S. *Amazon* and her sister ships will be fitting members of the Fleet and will engender pride and satisfaction in those who are associated with them.

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Ship Department Comment

Olympus Resilient Mountings: Following successful trials at Ansty and NGTE with Mark 3 mountings, it is intended to evaluate these at sea in H.M.S. *Amazon* in the near future. For a full description of the mounting, see *J.N.E.*, Vol. 21, No. 3.

Olympus Re-acceleration Stall: This problem has been overcome by slugging of the acceleration in the control system and this has been entirely successful. It is intended that this will be backed up by an on-engine slug working in parallel with the control modification, and this will give additional safeguards when in hand control.

Olympus Distributor/Burner Idling Problems: These are recognized and design investigations are currently in hand with a view to fitting pressurizing valves in lieu of the distributors. Shore development trials to date have shown that these have successfully overcome the problem. The Tyne engines already have pressurizing valves incorporated.

Tyne Short-Life Combustion Cans and Fuel Pumps: The Tyne engines initially fitted in *Amazon* were life limited by combustion cans. The life of the replacement engines has been doubled by fitting improved combustion cans. Limitations with existing fuel pumps will also be overcome with the introduction of springless fuel pumps. It should be noted that on-engine fuel pumps can be readily exchanged without changing the GTCU.

Compressor Washing: The use of WD 40 inhibition is an essential part of the compressor cleaning procedure assuming that the engine is not going to be used immediately. Present instructions are that compressors should be washed every 24 hours to prevent salt build-up. Observing the operational limitations, trials are at present in hand to extend the period between washes and this will result in reduced usage of WD 40.

Olympus and Tyne Gas Turbine Intakes: Trials at NGTE have demonstrated that a three-stage filtration system is required to meet the present laid-down standards. It is intended that three-stage filters will be fitted to the last two ships of the class during the build with provision for fitting three-stage filters to the remainder of the class. Following trials in *Amazon*, further modifications to realize the full potential of the two-stage filtration system have been successfully carried out and demonstrated in *Antelope*. These will be completed in *Amazon* as soon as possible.

Shaft Brakes: The brake problems have been the subject of intensive investigation and a long modification programme. The first modified set will be available for fitting in 1975.

Propulsion Controls: The problems associated with the control system and particularly earth isolation are being urgently investigated.

CPP System: Although many of the problems noted by *Amazon* have now been overcome, subsequent failures of pumps have demonstrated the high standard of system hygiene required. Recent experience with *Amazon* tends to support this and has resulted in greater system reliability.

Leaking Propeller Non-return Valves: Subsequent examination of the air non-return valves removed from *Amazon* showed that modification was necessary to make the system fully operational. Modified valves will be fitted to *Amazon* at the earliest opportunity.

Auxiliary Drive Shearpin Failures: Whilst the problems with the CPP and SW pump drive pins has been solved, solid pins remain at present in the shaft-driven LO pump drive and further work is being done to identify fully and resolve the problem.

Generator Low-Load Running: Present Fleet policy is to run two diesel generators but, as a result of the low-loading experiences in *Amazon*, single generator trials are being planned.

Boiler Unreliability for Light Loads: Trials are being carried out to examine the operation of the high and low boiler-firing rates. It is not possible to fit electric heating elements in the existing calorifiers but consideration is being given to changing them for steam/electric or all electric calorifiers.

Air-Conditioning System: On completion of fault correction to the air-conditioning system, full tropical trials were successfully completed when the ship was in the West Indies.